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How to Use the CSA B415 Performance Standard to Improve Furnace Efficiency

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Executive Summary

To help the wood-burning appliance industry develop more efficient appliances, and to help the consumer to select the best appliance for his/her requirements, the Canadian Standards Association has developed a methodology for rating the efficiency of, and the emissions from wood-burning appliances in the residential range. Manufacturers may use a portion of this test methodology, the dilution tunnel sampling procedure, in order to do their own performance testing. This testing tool gives manufacturers the opportunity to do serious development work on their appliances with confidence and at low cost.

Because B415 performance testing and appliance labeling is not mandatory in Canada, it is not being done. On the other hand the Environmental Protection Agency of the U.S.A. has legislated maximum levels for particulate emissions from wood heaters for sale in the States after July, 1988. American manufacturers have been forced to react and are scurrying to improve their products before the deadline, and Canadian manufacturers who export to the U.S.A. are doing the same.

This report documents the reliability of the dilution tunnel sampling procedure as a tool which can be used by Canadian manufacturers of wood heaters to develop cleaner-burning products. In the case of one of the better furnaces on the market, the addition of a catalytic block plus a brick liner reduced emissions by more than 50% and improved efficiency by 21%, from the 65% level to the 79% level, with a consequent reduction in wood consumption.

The major reduction in emissions means a cleaner chimney and therefore a safer chimney. In addition, since the chimney is cleaner and less prone to chimney fires, it will remain in good condition for a longer period of time.

Résumé

Dans le but d'aider à la recherche et au développement de meilleurs appareils à combustibles solides pour le secteur résidentiel, et dans le but de fournir aux consommateurs une base de comparaison de la performance de ces appareils, l'Association canadienne de normalisation (ACNOR) a développé une méthodologie permettant d'en évaluer le rendement, les émissions particulaires et les émissions d'oxyde de carbone. Les manufacturiers peuvent se servir d'une partie de cette procédure, le tunnel de dilution, pour faire leurs propres essais, à l'usine. Cet outil leur permet de faire un travail sérieux de développement sur leur propres appareils, avec confiance et à bas prix.

Parce que les essais et l'étiquettage, selon la norme B415 M1986, ne sont pas obligatoires au Canada, l'industrie n'a pas mis cette norme en application. Par ailleurs, l'Environmental Protection Agency (EPA) des Etats Unis a imposé des limites pour les émissions de particules par les appareils à combustibles solides qui seront vendus aux Etats Unis après le premier juillet 1988. Les manufacturiers américains ont dû réagir et sont engagés dans une course contre la montre pour rencontrer cette échéance. Les manufacturiers canadiens qui exportent aux Etats Unis font de même.

Ce rapport vérifie la fiabilité du tunnel de dilution comme outil de développement pour les fabricants canadiens qui veulent développer des appareils qui brûlent plus proprement. Cette étude démontre comment on a pu réduire de plus de 50% les émissions d'un bon appareil de chauffage central, tout en améliorant son rendement de 21%, soit d'un niveau initial de 65% à un niveau final de 79%, entraînant une réduction proportionnelle dans la consommation de bois.

La réduction des émissions entraîne la diminution des dépots de créosote dans la cheminée, créant par conséquant une situation plus sûre. De plus, une cheminée plus propre sera moins disposée aux feux de cheminée et aura une longévité accrue.

Scope

This report describes a procedure which wood heater manufacturers may use for testing the performance of their own appliances in order to develop more efficient, cleaner-burning and, therefore, more competitive products.

The first section describes the Canadian Standards Association (CSA) B415 test methodology. Emphasis is placed on one part of this methodology, the dilution tunnel test, because it is more appropriate to manufacturers for in-house testing. Costs and materials required for this procedure are listed.

The second section demonstrates how B415 can be used in woodstove development. A wood-burning appliance is modified several times and after each modification it is tested in order to determine the effect of that modification on performance.

Note: Heat output is expressed in MJ/h, which is roughly equivalent to 1000 Btu/h (1 kJ/h = 0.95 Btu/h).

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I INTRODUCTION

Most North American manufacturers develop their wood-burning appliances without any performance testing. They ensure that the appliance complies with the appropriate safety standards, such as CSA B366 for free-standing stoves, but do not make much effort to improve its efficiency and to reduce its emissions. There is no Canadian regulation which controls efficiency or emissions of residential wood-burning appliances. Until recently manufacturers who tried to improve the performance of their appliances did so only in the hope of eventually benefiting through favorable word-of-mouth advertising from satisfied customers. Since there was no standard rating procedure, performance was "improved" by guessing at modifications which they "thought" would improve their appliance; they were not equipped to measure the results.

In the United States the Environmental Protection Agency (EPA) recently imposed regulations on emission levels from wood-burning appliances. These levels must be met by July 1988. The maximum limit of 8.5 grams/hour of particulate matter for non-catalytic appliances (5.5 g/h for catalytics) will become compulsory for all woodstoves[1] by July 1988. By July 1990 the maximum limits will be lowered to 7.5 grams/hour (4.1 for catalytics). It might be argued that this will do little to reduce global air pollution, but American consumers who buy the new appliances will benefit through a large decrease in the number of chimney fires and through reduced chimney maintenance costs. Since the emissions levels are calculated on a time-averaged basis rather than heat-output basis, the larger the appliance, the more difficult it is to meet the standard's maximum emission limit.

Very few of the Canadian wood heaters which are presently manufactured could meet the U.S. emission regulation for 1988 (8.5 grams/hour). Any Canadian appliance that does not comply cannot be sold in the U.S.A. Unless Canadian manufacturers pick up the challenge, they are going to lose the right to compete in the largest market in the world because they cannot meet its pollution control requirements. Will American manufacturers who cannot meet the U.S. pollution requirements dump their left-over wood-burning appliances on the Canadian market? Will quality-conscious Canadians start buying American stoves because they

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[1] The EPA standards do not apply to wood-burning furnaces and boilers at this time, because test procedures still have to be tailored to these appliances. Also, there is a technically illogical grandfather clause which allows manufacturers to have appliances tested to the statistically-indefensible Oregon standard (which in effect, allows higher emission levels) at any time up to October 1, 1987, and to sell stoves which meet this standard, until the end of 1989.

meet higher performance criteria? Canadian manufacturers must react quickly to develop products that will meet this new challenge. Seventeen percent of all solid fuel burning appliances, below 250000 Btu/h, manufactured in Canada in 1986 were exported.

Several possible test methodologies can be used for product development purposes. The CSA B415 Preliminary Standard was published in 1986. Because our standard is not mandatory and because of the high cost of certification by an "official" laboratory ($6000 to $12000) no manufacturer has had his/her appliances tested to this standard. A few manufacturers do use it in their own shop, to conduct developmental work on their appliances. Other manufacturers use the services of research and development laboratories which are not certified but which are equipped for B415 testing. When using these facilities, a manufacturer has all the flexibility he needs to try a variety of modifications on his appliance without having to go through the formal test procedure each time. Often, modifications are based on dilution tunnel data, and only the "final" design is tested to the full B415 standard.

II PERFORMANCE TESTING METHODOLOGIES

A number of wood-burning appliance test methodologies have been developed in recent years. Although many questions persist as to the precision of each methodology, some methods have been adopted by regulatory bodies and this automatically makes them more important. In Canada the CSA B415 test methodology was developed. It is virtually identical to the test procedure developed and promoted by the Wood Heating Alliance in the U.S.A. However, the EPA adopted the well-publicized Oregon methodology, which means that Canadian wood stove manufacturers who wish to sell their appliances in the United States after July 1988, will require a performance certification based on one of the following three test methodologies:

- Oregon Method 7 (OM7) in the stack: method used by the Oregon Department of Environmental Quality (DEQ).

- Oregon Method 7 (OM7) in a dilution tunnel

- EPA Method 5G - Dilution tunnel sampling (formerly known as the ASTM procedure). It uses the (small) Oregon fuel load, not the ASTM fuel load.

Only tests by an American certified testing laboratory using one of the above methodologies is recognized by EPA.

III THE CSA B415 STANDARD

This standard is entitled, "Performance testing of solid fuel burning appliances". It describes a procedure for measuring the overall efficiency and the emissions level of a free-standing wood-burning appliance at various firing rates. The test data permit us to choose between two stoves designs on the basis of efficiency and on the basis of the quantity of incomplete combustion products emitted. An appliance's emission level is a measure of its potential for chimney fires due to creosote and for air pollution.

The CSA B415 test involves the calculation of the chemical energy loss up the chimney (smoke) and heat loss up the chimney (hot gases). It also measures the total amount of particulates (tars and carbon) produced by incomplete combustion. Basically, the procedure involves the burning of a standard wood charge. During the combustion, flue gas temperature, CO_2, CO, O_2, and the steadily decreasing weight of the wood are measured continuously. The total amount of particulates is also measured for each test combustion.

The test is repeated at a minimum of four different combustion rates. An efficiency rating is obtained at each combustion rate.

as well as a value for carbon monoxide, hydrocarbon and particulate emissions. By comparing the curves generated from these points with the curves for other wood-burning appliances, it is possible to evaluate their relative performances. By comparing the curves from an appliance before and after modification, one may determine which modifications are best. For development purposes, it is often found that more than four combustions are necessary to get a clear picture of the appliance's performance.

The CSA B415 method differs from the current American methods (e.g. method 28) in that they utilize different wood charges. The U.S. tests use 7 pounds of wood for each cubic foot of combustion chamber volume while the Canadian standard uses 12. It can therefore be expected that the two tests will indicate different particulate emission rates.

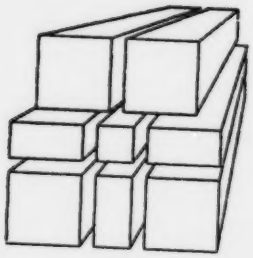
The Oregon standard permits a test agency to discard any unfavorable test points; which means that an agency will continue to repeat burns until acceptable test points are obtained (or money runs out). The EPA procedure does not permit such discarding of unfavorable data.

Another shortcoming of the present EPA standard is the "grams per hour" parameter on emission limits. This time-weighed average (g/h) allows manufacturers to design appliances more in function of long burns than in function of clean burns. The appliances may not necessarily burn cleanly but, because they can prolong the combustion test, they manage to lower their average particulate emissions below the EPA hourly limit. Appliances which pass the Oregon tests after a high number of rejected combustions, and appliances designed to pass the EPA standard with a long "tail end" burn, will no doubt produce emissions higher than regulation limits when operated domestically.

IV MODIFICATIONS TO THE B415 METHODOLOGY TO PERMIT FURNACE TESTING.

The B415 test methodology can be used to test wood furnaces. Since B415 was designed for testing manually-controlled space heaters, at constant settings, the procedure has to be modified to deal with thermostatically controlled central heating systems. The on/off control must be operated in such a way as to provide constant output, e.g. 15 MJ/h or 25 MJ/h, etc.

A complete CSA B415 test normally includes burns from the lowest to the highest outputs attainable by an appliance. However, the furnace tests described in this report were limited to outputs between 15 and 30 MJ/h, which are in the normal overnight operating range of a single family dwelling.



The wood charge used for the furnace tests consisted of 9.7 kg of Douglas-fir. The pieces were 41 cm long and had a moisture content of 18% w.b.[2]

[2] "18% w.b." means 18 percent, wet basis. The lumber industry usually describes lumber moisture content in terms of dry basis (d.b.) whereas most industries use wet basis.

V DILUTION TUNNEL TESTING

Dilution tunnel testing which is partial B415 testing, is particularly useful for manufacturers because it requires a minimum of training , equipment and setup. The method measures only the appliance's particulate emissions; it will not measure efficiency or appliance output. For manufacturers who wish to compare their appliance emissions to the future U.S. standards, the dilution tunnel method will provide particulate emissions in grams/hour. Supplementary information may sometimes be gained by using grams of particulates per kg of fuel burnt. If the manufacturer's objective is to certify to the American (EPA) standard, the test should be performed using method 5G[3] (see bibliography).

The apparatus necessary for dilution tunnel testing is shown in Figure 1[4]. The total volume of flue gas leaving the appliance is routed through a funnel where it is mixed with air. Throughout the burn cycle, a known proportion of the diluted gas is pumped through a pre-weighed filter. The filter is re-weighed after the burn. The difference is the weight of the particulate matter trapped by the filter. Since the sample that was passed through the filter was a known proportion of the total volume, the total weight of the particulates emitted can be calculated. This weight can be averaged over time to give a reading in grams/hour or it can be divided by the mass of dry wood burned to give a reading in grams per kilogram of fuel. The official sampling method for particulates is described in Appendix A.

The total cost of installing a dilution tunnel testing equipment is between $10,000 and $12,000. A breakdown of these costs is provided in Appendix B.

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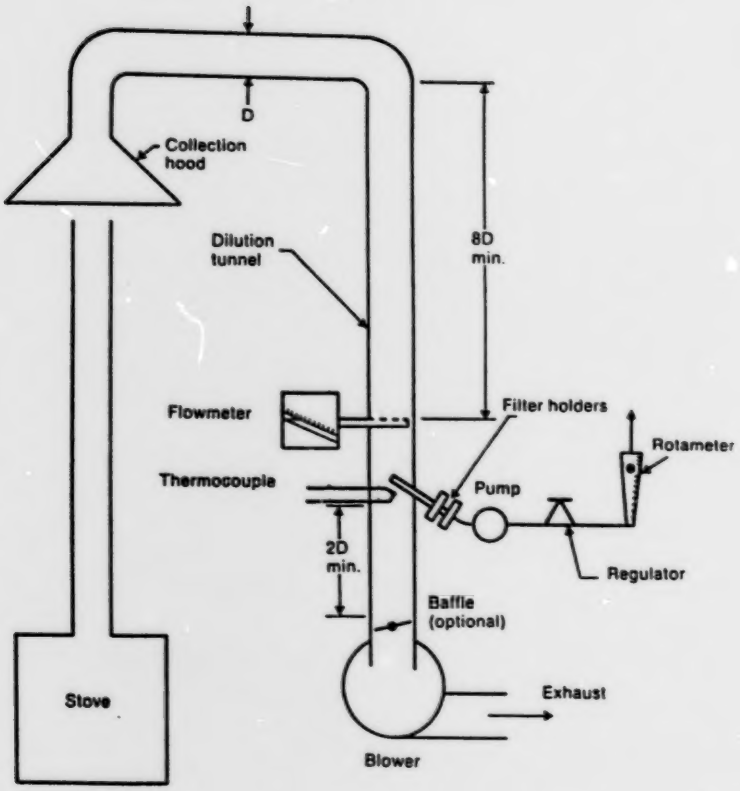
[3] The wood charge for method 5G is described in EPA method 28A.

[4] From CSA Preliminary Standard B415-M "Performance Testing of Solid Fuel Burning Appliances"

Figure 1.



Typical Noncondensing Dilution Tunnel Apparatus for Measurement of Particulate Emissions

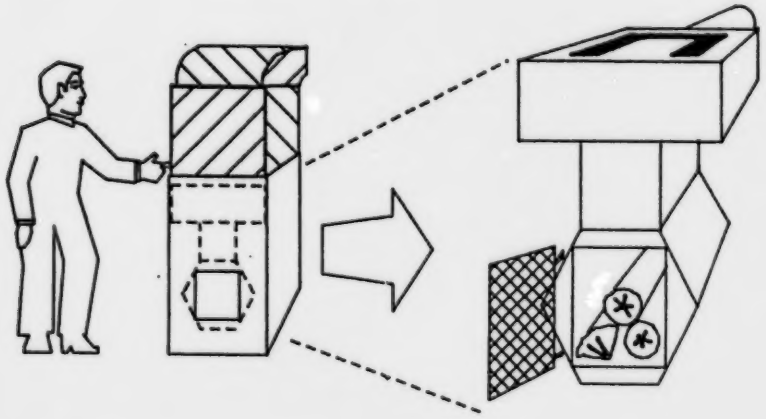
VI MODIFICATION OF A WOOD-BURNING FURNACE TO IMPROVE PERFORMANCE

NOTE: The modifications described in this section are specific to the appliance and should not be generalized to other appliances without prior performance testing.

1. Original Appliance Design

A wood-burning furnace which had previously been tested by IRTA, and which had a relatively high efficiency, was chosen for modification. After each modification the furnace was subjected to a full B415 test, including the dilution tunnel, to determine the effect of that modification. The dilution tunnel test only would have been adequate for the improvement program, but we wanted to confirm the correlation between the complete procedure and the tunnel test only.

The wood-burning furnace used for these tests is CSA certified[5] and has a 60-litre (2.1 cu. ft.) hexagonal-shaped combustion chamber. The combustion chamber walls are constructed of a single layer of 3/16-inch steel plate. The blower pushes air directly against its walls, thus constantly cooling the combustion chamber. After leaving the combustion chamber, the combustion gases pass through a ceramic fiber tunnel, before reaching the heat exchanger. The heat exchanger itself has a total surface area of 1.5 square metres. This furnace is rated by the manufacturer at 40,000 Btu/h (42 MJ/h or 11.7 kW/h).

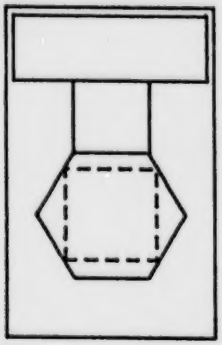


5 This appliance complies with CSA standard B366.1 "Solid Fuel Fired Appliances for Residential Use", which is essentially a safety standard.

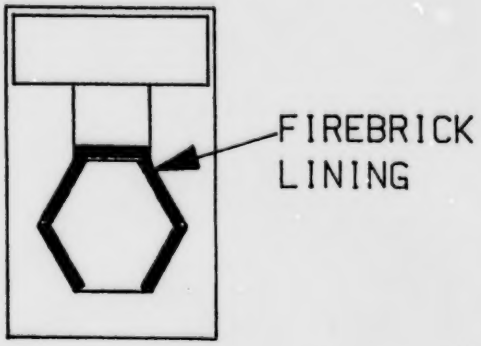
2 Modified Design to Improve Furnace Performance

a. Insulating the combustion chamber

The first modification made on the appliance was to insulate the furnace's combustion chamber. Theoretically this should prevent the quenching of flames on the cool combustion chamber walls, raise the combustion chamber temperature and hence improve the appliance's performance. The furnace's combustion chamber was insulated first with firebrick, then with a metal liner (after the firebrick was removed).



Original unlined firebox

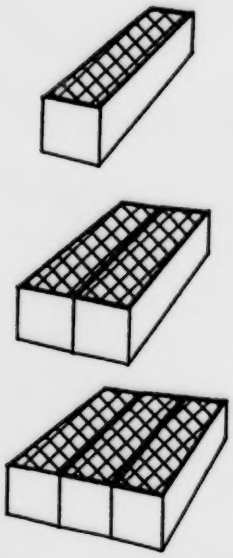


Firebrick-lined firebox

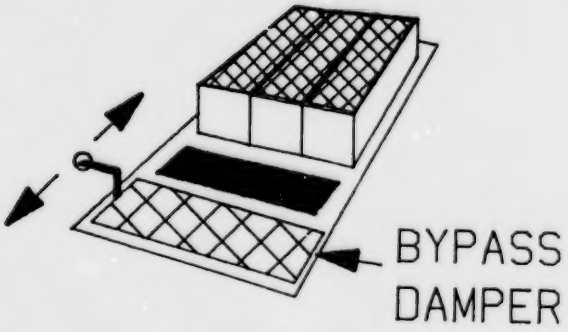
b. Retrofitting the appliance with catalytic combustor blocks

Catalytic combustors have long been used to lower the emissions from wood-burning appliances. Unfortunately catalytic blocks have not been used very successfully in wood-burning furnaces because of manufacturer reaction to the added cost, and because of customer suspicions about their difficulty of operation ("you can't burn coloured paper") and duration ("you might have to replace the catalyst block every year"). Additional costs and absence of demand have led to almost total absence of research on the part of furnace manufacturers. It is often forgotten that catalytic combustors lower emission levels, lessen the chance of chimney fires and reduce the frequency of flue maintenance.

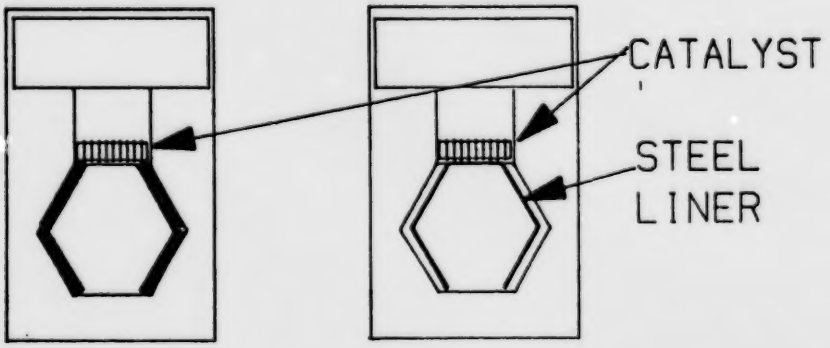
Even though the original furnace was not designed for use with a catalytic combustor block, it was modified to accept blocks of three different sizes. A sliding by-pass was also added to route the combustion gases around the catalytic combustor during light up.



Catalytic combustor blocks.



Catalyst holder with by-pass



Firebrick-lined firebox with catalytic combustor

Steel-lined firebox with catalytic combustor

The firebrick lined furnace was first tested with one catalytic block (130 cm^2), then with two catalytic blocks (260 cm^2), and finally with three catalytic blocks (390cm^2). Furthermore, the two-catalytic block design was also tested without a combustion chamber liner and then with a steel liner.

3 Analysis of B415 test results

Test results are shown in graphical form.[6] The dilution tunnel test results for eight firebox configurations are presented in graphs 1A, 1B, 2A, 2B, 3A and 3B. The B415 results are presented in graphs 1C, 1D, 1E, 2C, 2D, 2E, 3C and 3D.[7] CSA B415 dilution tunnel data should not be compared to EPA emissions requirements because they were generated using a B415 fuel charge of 12 pounds per cubic foot compared to 7 pounds per cubic foot for EPA.

A. Dilution tunnel vs complete B415

Dilution tunnel data led to very similar design conclusions in the heat output ranges which were investigated.

B. Insulating the combustion chamber (Graph 1B)

A firebrick or metal liner provided no conclusive reduction in particulate emissions over the original appliance design when no catalyst was used.

C. Retrofitting furnace with catalytic combustor blocks (Graphs 2A, 2B)

Catalytic combustors significantly reduced emissions. Catalytic combustor blocks with larger surface areas (2 and 3 blocks) were more effective at higher burn rates. The reduction in particulates for a single block is 53%, whereas double and triple blocks provide a 65% reduction.

If catalysts are used, steel or brick liners provide additional reduction in emissions, in the heat output ranges tested.

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[6] Each curve is a computer-generated second degree curve-fitting of the results of four to six combustions. Curves are only approximations and become more precise as additional points are added. Four-point graph curves have a fair margin of error and should be interpreted carefully. A manufacturer having to choose between two designs giving similar results should run more tests to arrive at a more dependable conclusion.

[7] Dilution tunnel data are presented both in grams per hour and grams per kilograms of dry wood against a burn rate in kg/h (which is easily calculated by a manufacturer). On the other hand, B415 yields efficiency figures (%), Carbon monoxide emissions (in grams per MegaJoule) and particulate emissions (in grams per MegaJoule) against an output rate in MJ/h (only obtainable with total B415 calculations).

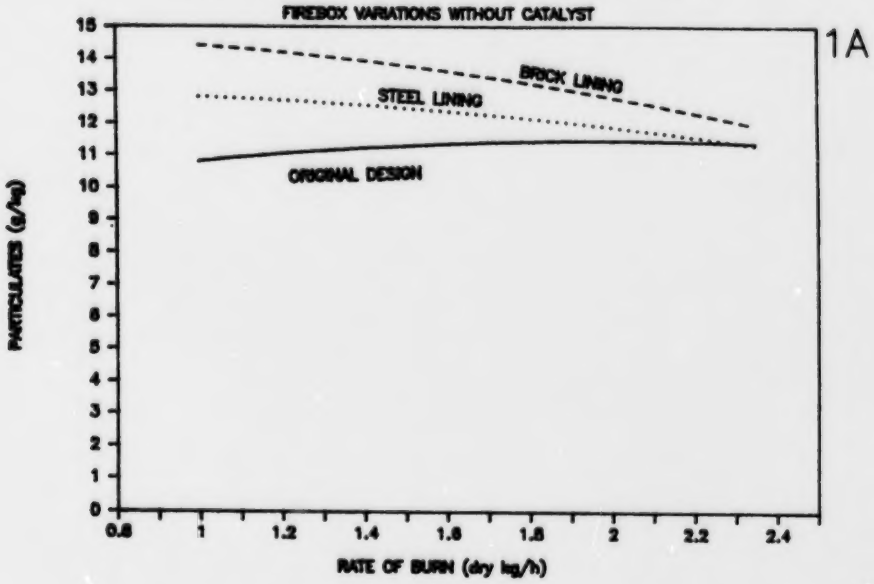
D. Decreasing furnace's heat exchanger area

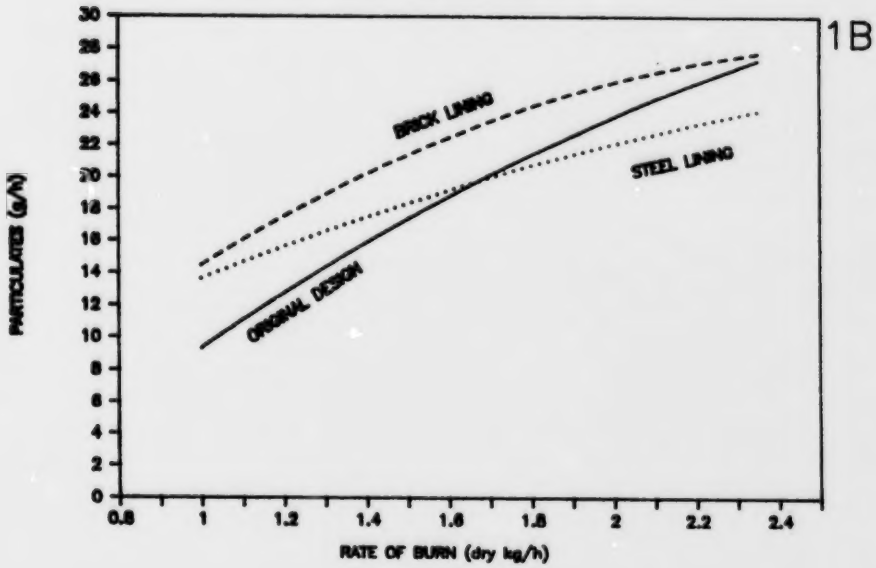
Without any insulation, this appliance condenses (in laboratory conditions) when the average B415 stack temperature is below 90° C. This normally happens when the combustion rate drops below 1.8 kg/h. We observed no noticeable improvement in the furnace's performance with a 15% reduction in heat exchange area, at burn rates near 1 kg/h. There still was considerable condensation in the flue pipes. However, condensation was completely eliminated in the 1 kg/h range by a 30% reduction in heat exchange area. If this appliance was to be designed for use with catalysts, in the 15 to 30 MJ range, such a reduction in heat exchanger area would be necessary. The marginal loss of efficiency would be largely offset by an improvement in overall system performance.

VII ECONOMIC IMPLICATIONS

The use of a double-area catalytic block in conjunction with a brick lining improved efficiency from 65% to 80% at 24 MJ/h. This implies that a house which used 5 cords a year with the original furnace design, would require 4 cords a year with the new design. At a cost of $100/cord for split, dry firewood, this would mean a saving of $100/yr and the added convenience of less wood to carry and a cleaner chimney. The improved unit could probably sell for approximately $300 more. The catatlytic block would probably have to be replaced every 3 to 5 years at a cost of $150. The net gain would be a slightly lower fuel cost with a radically improved performance and a cleaner, safer chimney with a longer life.

PARTICULATE EMISSIONS (dilution tunnel)

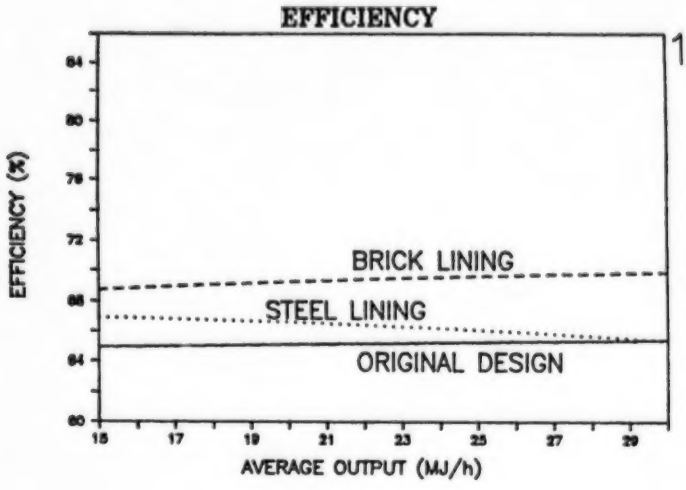




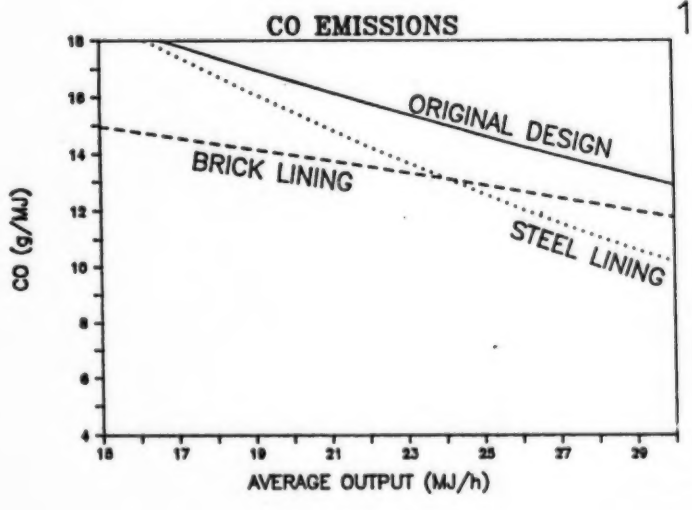
CSA B415

FIREBOX VARIATIONS WITHOUT CATALYST

1 C



1 D



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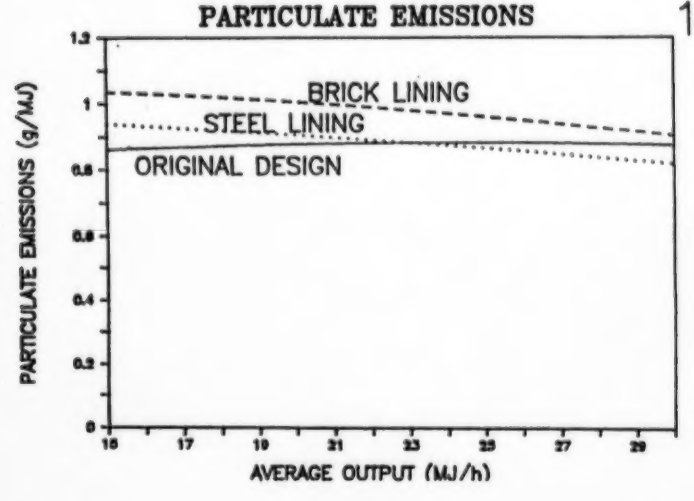
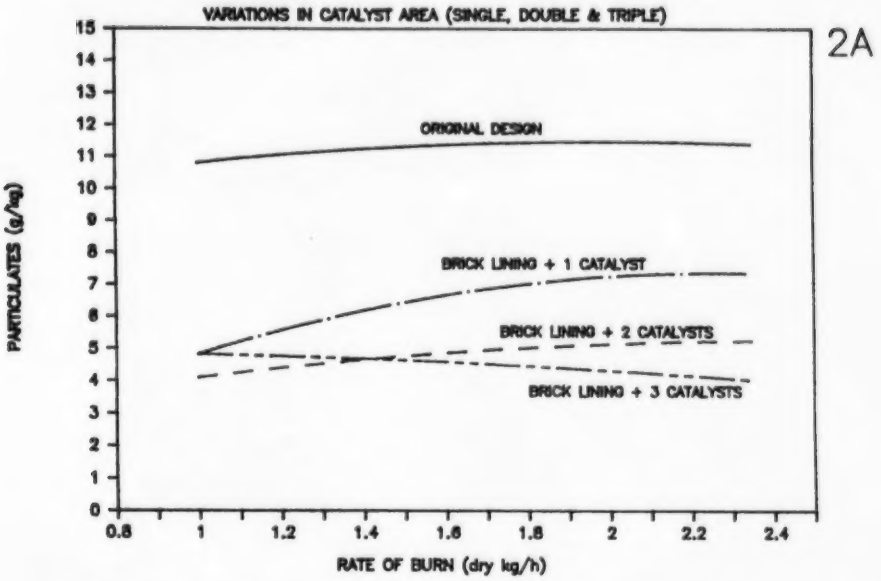
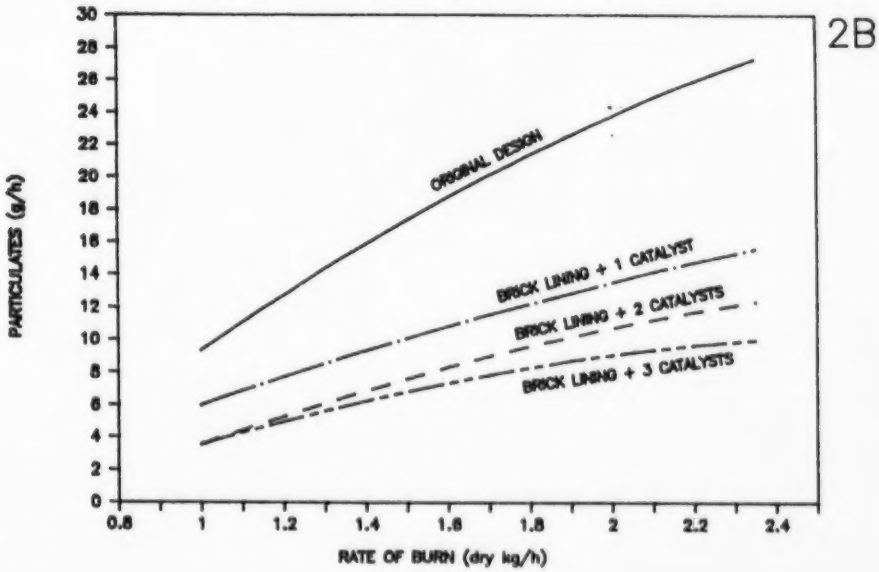


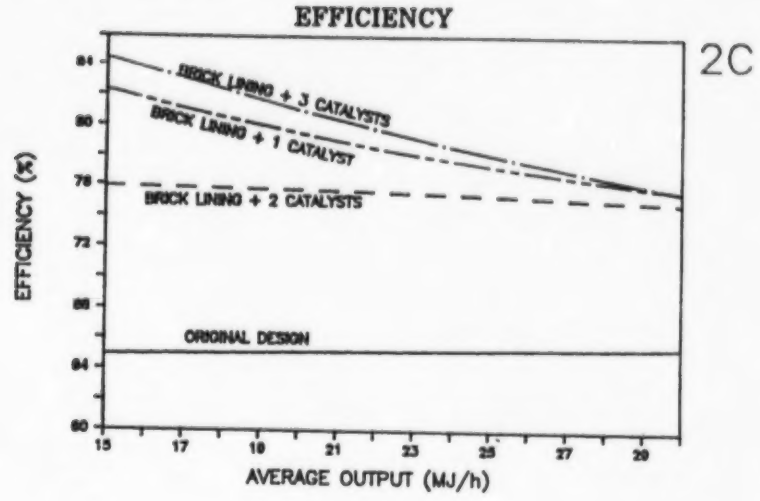
PARTICULATE EMISSIONS (dilution tunnel)

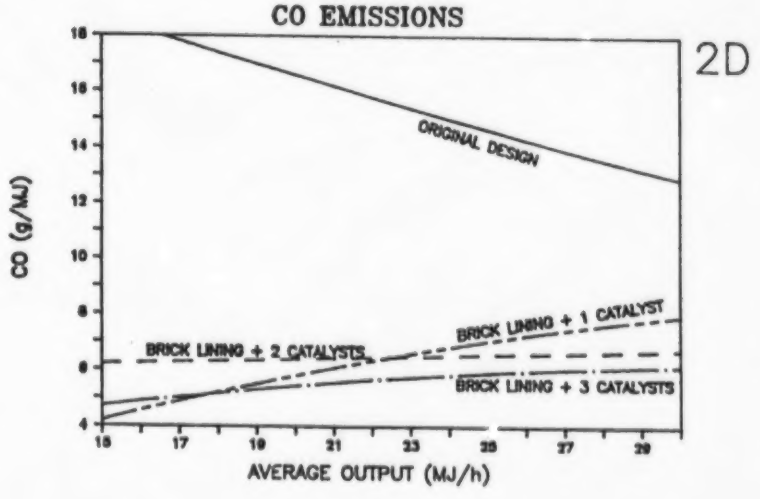

VARIATIONS IN CATALYST AREA (SINGLE, DOUBLE & TRIPLE)
2A
PARTICULATES (g/kg)
ORIGINAL DESIGN
BRICK LINING + 1 CATALYST
BRICK LINING + 2 CATALYSTS
BRICK LINING + 3 CATALYSTS
RATE OF BURN (dry kg/h)

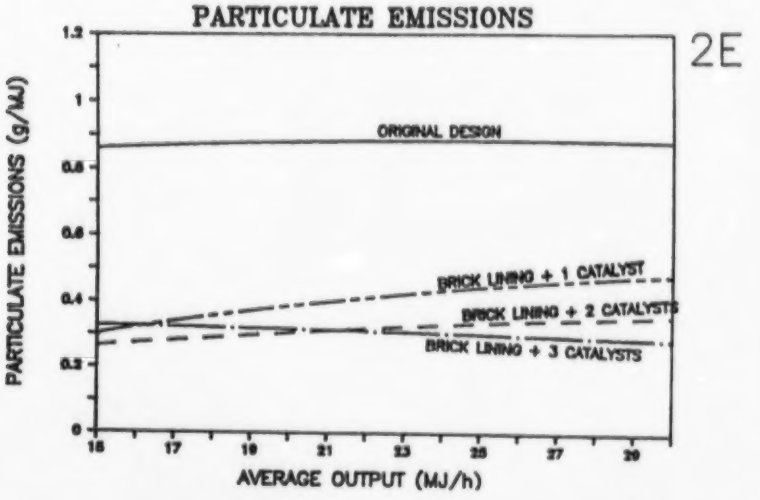


CSA B415

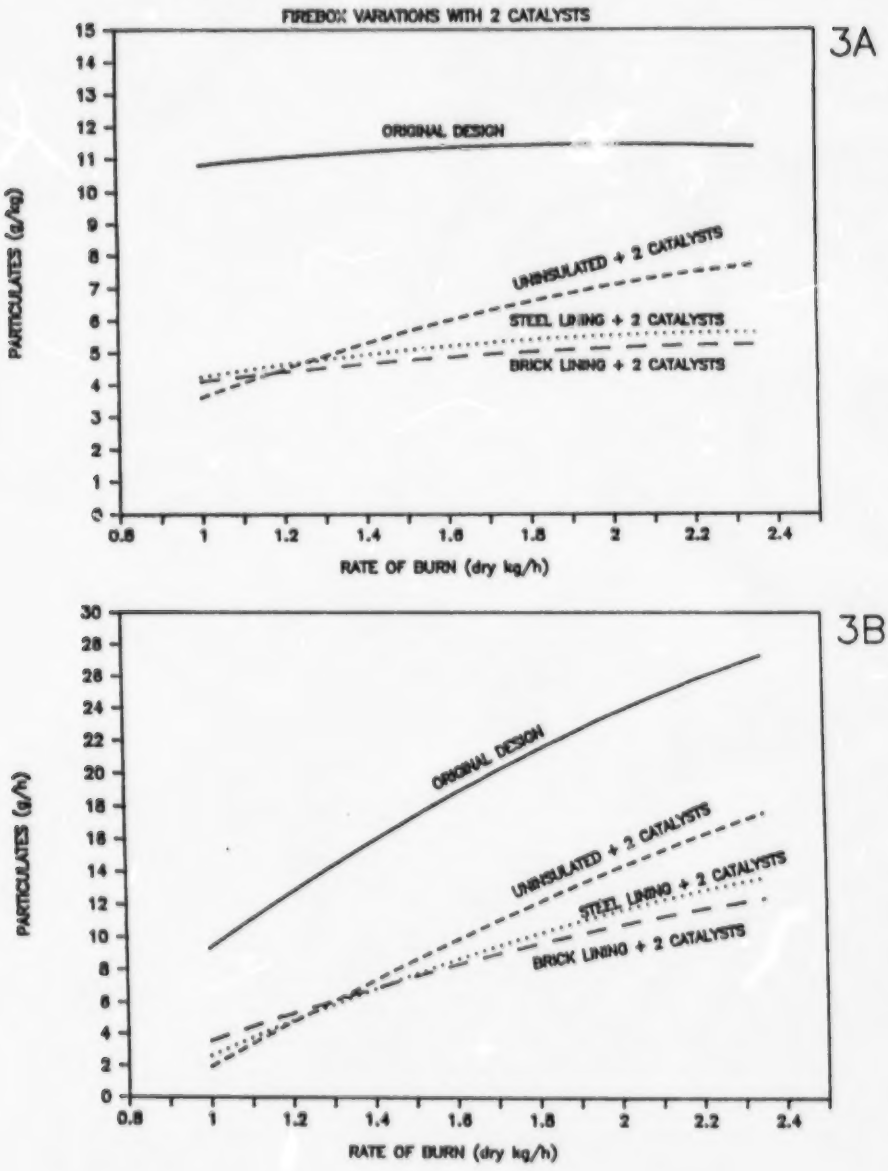
VARIATIONS IN CATALYST AREA (SINGLE, DOUBLE, TRIPLE)





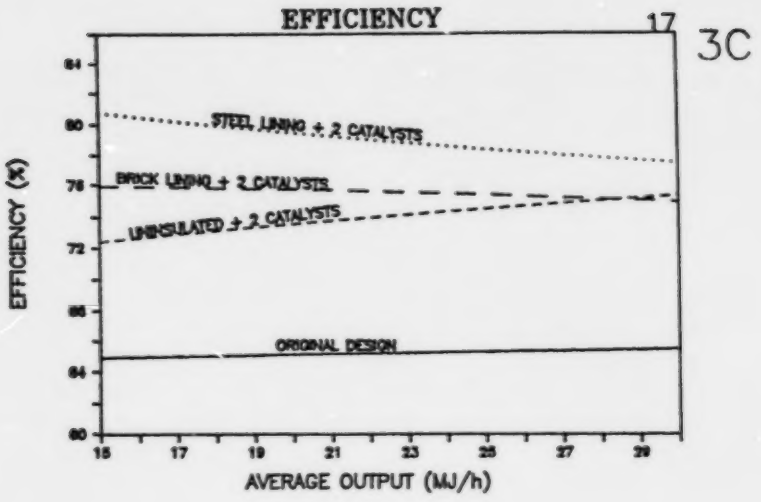


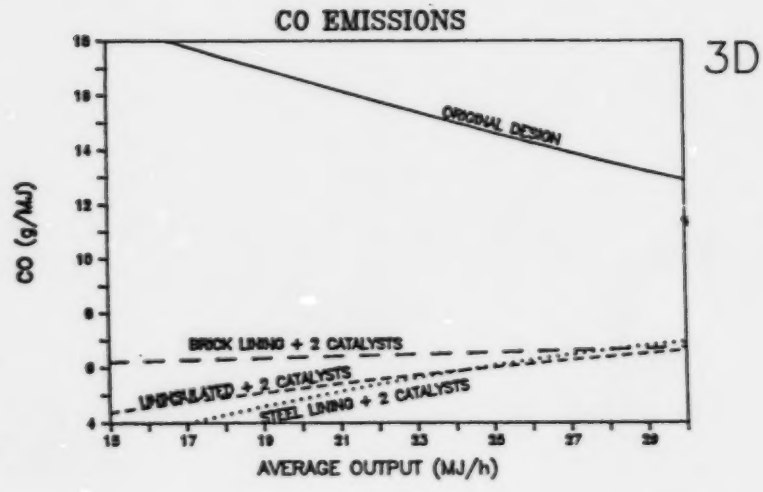
PARTICULATE EMISSIONS (dilution tunnel)

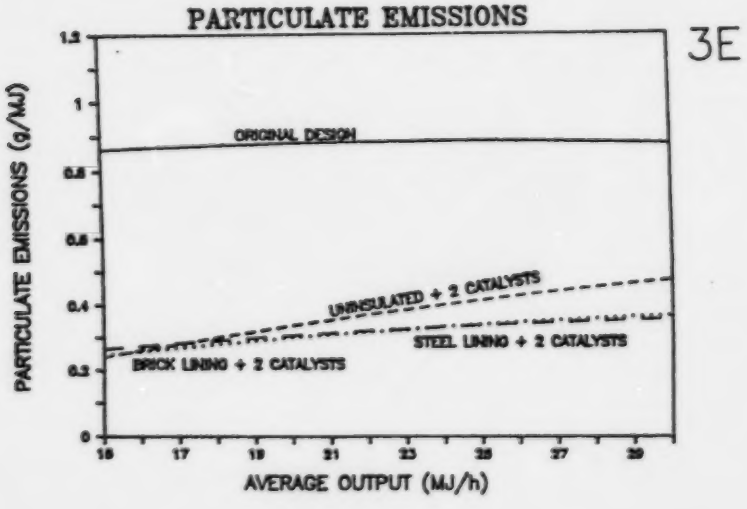


CSA B415

FIREBOX VARIATIONS WITH TWO CATALYSTS







VIII CONCLUSIONS

The dilution tunnel tests demonstrate how emission level changes after appliance modification can be measured and thus measure the improvement due to the modification. Dilution tunnel test results are close enough to total B415 test results to provide a reliable development tool. If dilution tunnel data alone had been used, very similar conclusions would have been made regarding the best design.

With such an accessible tool, it is high time Canadian manufacturers picked up the American regulatory challenge and developed competitive appliances both for the Canadian and the U.S. market.

Addendum:

The modifications which were shown in this report are specific to the appliance and should not be generalized to other appliances without prior performance testing. We modified another furnace with a large (162 litres, approximately 5 cubic feet) uninsulated firebox by adding a metal liner. This furnace had aroused our curiosity since it was extensively used in a number of northern villages that had experienced frequent chimney fires. After modification, particulate emissions at 30 MJ/h decreased from an original level of 1.4 g/MJ to 0.6 g/MJ, a 57% reduction in particulates.

This modification cost less than $30, including labour, and it was extremely simple to perform. Other uninsulated appliances could be modified in a similar manner, probably for a substantial improvement in performance. Although this seems like an interesting approach to large furnaces, it can only be confirmed by testing each appliance design.

IX Appendices

A. Dilution tunnel test methodology (CSA B415-M1986)

B. Dilution tunnel equipment

5.5 Apparatus for Particulate Sampler

5.5.1

The equipment used for measuring particulate emissions is based on a constant flow sampler. The apparatus consists of a sample-conditioning system (noncondensing dilution tunnel) and a sample collection system (filter train). Figure 2 is a schematic of a typical apparatus.

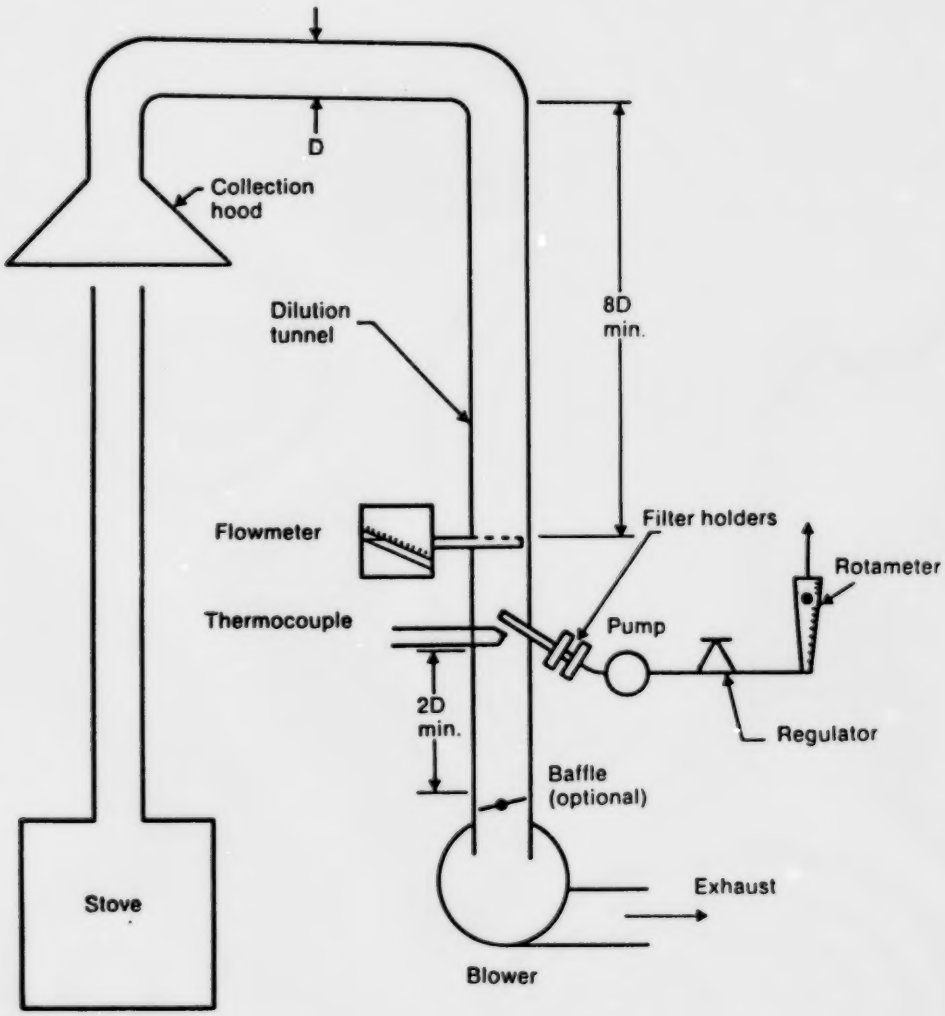


Figure 2
Typical Noncondensing Dilution Tunnel Apparatus for Measurement of Particulate Emissions

5.5.2

The sample-conditioning system shall include a collection hood, a dilution tunnel, a blower and optional baffle, a thermocouple, and a standard Pitot tube flowmeter. The tunnel shall be circular in cross section and shall be between 10 and 46 cm (4 and 18 in) in diameter.

5.5.3

The dilution tunnel shall entrain 100% of the flue gases during the entire test. The flow shall be large enough to eliminate water condensation in the dilution tunnel, shall be kept constant within ±2% during the test run, and shall be at least 3 m/s at 21°C (10 ft/s at 70°F).

5.5.4

The system shall operate such that the tunnel flow is turbulent (Re > 20 000) and completely mixed.

5.5.5

At all times during the test the gas temperature in the tunnel shall be less than 52°C (125°F) and the ratio of tunnel flow to stack flow shall be at least 10.

5.5.6

The temperature in the tunnel shall be measured with a thermocouple having an accuracy of ±1.6°C (3°F) in the range of 15—52°C (58—124°F).

5.5.7

The flow in the tunnel shall be maintained such that the ratio of the average mass flow rate in the tunnel to the fuel mass consumption rate is between 100:1 and 400:1.

Note: ***These provisions are intended to keep the appliance emissions diluted enough to form a well mixed flow in the tunnel and to avoid condensation but not overly diluted so as to affect test results. Cleaner-burning appliances produce emissions requiring use of dilution ratios at or near the lower limit of the method to meet the filter-loading requirement in Clause 5.5.15(d). Humid ambient conditions may require operation near the upper end of the allowable range.***

5.5.8

The collection hood and dilution tunnel shall be made of electrically conductive material that is grounded, that does not react with the exhaust components, and that does not contribute particulate or condensible material to the test gas mixture.

5.5.9

The tunnel shall be free from flow disturbances such as bends, expansions, or contractions for at least eight tunnel diameters upstream and at least four diameters downstream from the sampling probe.

5.5.10

The sample collection system shall consist of a probe, filters and filter holders, and a system for inducing and measuring the sample flow.

5.5.11

The sample probe shall comply with the following:

(a) the probe opening shall face upstream and be located near the tunnel centreline approximately 2 tunnel diameters downstream from the Pitot tube;

(b) the probe shall be a sharp-edged nozzle with an inside diameter of from 0.5 to 1.1 cm (3/16 to 7/16 in);

(c) the probe shall be free from the influence of any wake or eddy;

(d) the probe and all connecting tubing shall be made of glass or stainless steel; and
(e) the flow rate through the particulate probe shall be maintained at a constant value within ±2%.

5.5.12

The distance from the sampling tip to the filter holder shall be not more than 61 cm (24 in). The probe and tubing shall be free from sharp bends.

5.5.13

The filter holder shall comply with the following:
(a) the filter holder shall provide a positive seal against leakage from the outside or around the filter; and
(b) the backup filter holder shall be located 25—100 mm (1—4 in) downstream from the primary filter holder.

5.5.14

The filter temperature shall be measured at a point between the primary and secondary filter and shall remain between 21 and 32°C (70 and 90°F) during the test.

5.5.15

The particulate filters shall comply with the following:
(a) the particulate filters shall have a diameter of at least 47 mm (1.8 in);
(b) the filter shall be A/E binder-free glass fibre with 99.9% retention of particulate less than 0.3 μm (0.0118 μin);
(c) the velocity of the sample flow through the filter surface shall be between 0.01 and 0.15 m/s (2.0 and 30.0 ft/min);
(d) sampling shall be conducted so that the loading on the primary filter is more than 10 mg but less than 50% of the filter weight, except that the loading may be less than 5 mg if the dilution ratio is less than 150:1 (see Clause 5.5.7), the filter face velocity is greater than 0.10 m/s (20 ft/min), and a single filter set is used for the entire set;
(e) filter weight shall be measured with a device having a resolution of at least 0.1 mg; and
(f) alternate filter sets may be used if loading is severe.

5.5.16

The sampling system shall be designed and located so as to provide constant flow unaffected by temperature fluctuations in the dilution tunnel.

5.5.17

The sample-flow-measuring device shall be capable of measuring flow rates with an accuracy of at least ±2% of the sample flow rate.

Appendix B.

Description and cost of equipment and consumables for dilution tunnel testing.

Equipment:

Weigh scale for wood heater: to determine coal bed weight and by consequence, the test duration, it is necessary to have the appliance fired on a weigh scale. Range: 0 - 300, +/- 0.05 kg. Cost: up to $5,500.

Weigh scale to determine quantity of particulate matter. This involves measuring minuscule quantities. A precision scale is necessary; it requires careful and precise handling. Range: 0-10 grams, +/- 0.5 mg. Cost: up to $4,000.

Instruments to measure flow in dilution tunnel (manometer + pitot tube). Cost: up to $400.

Rotameter: flow meter to measure and adjust rate of flow of sampling from dilution tunnel. Range: 0 to 5 l/m, +/-5% Cost: up to $300.

Temperature reading instrument for dilution tunnel and stack (thermocouple + meter). Range: 0 to 500°C. Cost: $250.

Sling psychrometer: to measure moisture content of dilution tunnel gases. Cost: $150.

Air pump to pump sample through filter. Range 0 to 10 litres/m. Cost: $400

Filter Holders: 47 mm filter holders Cost: from $250 each (plastic) to $450 (stainless).

Dilution tunnel (hood, flue pipe, blower ...) Cost: $1,000

Conditioning compartment to maintain test wood at 18%. Requires a humidifier. Cost: $500

Moisture meter to measure moisture content of wood. Range: 12% to 25% (dry basis). Cost: $500

Dessicator: Filters must be dried before initial weighing and they must be dried after test. This is done by storing the filters in an airtight container with a moisture absorbing chemical.

Timer: to measure duration of combustion.

Supplies:

Fuel: Douglas-fir lumber in certain specified sizes.

Filters: 47 mm filters

Petri dishes to store filters

Stainless steel tubing, plastic tubing

Moisture absorbent

Bibliography

Preliminary Standard CSA B415-M1986,
Performance Testing of Solid Fuel Burning Appliances
Canadian Standards Association
178 Rexdale Boulevard
Rexdale (Toronto), Ontario
M9W 1R3

Method 5G, filtration method only: ASTM P-180
ASTM
1916 Race Street
Philadelphia
PA 19103